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ABSTRACT

This booklet introduces the SM-14 (Scientific Method) Formula and lists characteristics of the scientific method. A history and progression of the scientific method is also featured. Contents include: (1) The Basic Principles of the Scientific Method; (2) Submitting Ideas Incorporating SM-14; (3) The 11 Stages of the SM-14 Formula and Famous Examples; (4) The Three Supporting Ingredients of the SM-14 Formula; (5) Everyday Problems and Decisions and Explanations of Methods and Method; (6) Helpful Information on Creativity, Decision Making, Invention, and Scientific Management; and (7) Guide and Worksheet for Applying SM-14. (YDS)

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YEAR 2000 EDITION

The Scientific Method Today

Your Guide to the Complete Method of Creative Problem Solving and Decision Making

SM-14

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Introduction to "The Greatest Idea of All Times"

Dear Knowledge Seeker,

The scientific method has earned the title of "The Greatest Idea of All Times." Put this idea to work for you in your problem solving and decision making.

This booklet contains today's most up-to-date, clear, concise and reliable information about the scientific method that has ever been offered.

Applied My Past Experience in Abstracting Basic Principles.
In my 35-year career of starting and expanding Edmund Scientific Company, my big job was abstracting basic principles of operation and of new products. In the past ten years I've zeroed in on the scientific method; purchased over 3,000 books; read professional journals, Internet web sites and reports; and set up extensive files. I've investigated the subject day and night, and considered all claims for and against the scientific method.

You Get the Benefit of All This Research.
You should take advantage of all the reliable knowledge presented here. Unfortunately the scientific method has not been adequately taught in our schools. I explain why in my other reports.Just as the scientific method has brought such great benefits to society, it can do great things for you too. — Good Luck — Get started today.

Norman W. Edmund

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Profits from the sale of this booklet are devoted to promotion of The Scientific Method.

This Is The Scientific Method

A Well-researched Description of the Problem Solving & Research Process

The SM-14 Formula for the General Pattern of the Scientific Method

MAJOR STAGES

PART I — ***Observation through Hypothesis***

1. Curious Observation
2. Is There a Problem?
3. Goals and Planning
4. Search, Explore, and Gather the Evidence
5. Generate Creative and Logical Alternatives
6. Evaluate the Evidence
7. Make the Educated Guess (Hypothesis)

PART II — ***Challenge through Suspend Judgment***

8. Challenge the Hypothesis
9. Reach a Conclusion
10. Suspend Judgment

PART III — ***Implementation, Peer Review***

11. Take Action

SUPPORTING INGREDIENTS

PART IV — ***Supporting or Operating Ingredients***

12. Creative, Non-Logical, Logical, and Technical Methods
13. Procedural Principles and Theories
14. Attributes and Thinking Skills

The research process is not just a collection of miscellaneous "scientific methods." Scientists and other researchers do not proceed in a haphazard fashion. Centuries of trial and error, research, discussions and debates have led to a realization of the general pattern of the scientific method. The pattern represents the major stages of how we obtain, refine and apply knowledge in all fields. The method of science has been called by many names, most commonly the scientific method. It is also a complete method of creative problem solving and decision making for all fields.

There are Eleven Major Stages (1-11) to The Scientific Method

Each stage (1-11) represents a different type of mental activity (usually aided by physical actions). The method is subject neutral.

Flexible Order of Use—While the stages are listed in the usual order of use, in actual practice they will be utilized in a very flexible manner as progress on complex problems is seldom smooth. In using the stages there will be: backtracking, skipping, false starts, looping, sub-problems, and other diversions.

The Supporting Ingredients (12-14) of The Scientific Method

These are included in the SM-14 formula as ingredients rather than stages to help people understand "the method" and as an aid to teaching it to students and others. Presenting only the stages doesn't give you a complete picture of the overall system. The scientific method is the master method of all methods. The word "method" in the term, "the scientific method," is a collective term for the stages. "Scientific" qualifies how scientists and others have historically utilized the stages of the method to accomplish results. Their methods, procedures and human activities are ingredients 12-14: Creative, Non-Logical, Logical, and Technical Methods; Procedural Principles and Theories; and Attributes and Thinking Skills.

The Complete System of Science and Problem Solving

The SM-14 formula embodies the complete method of science — its stages, techniques used, procedural principles and theories, attributes and skills needed and submission to the process of peer review at Stage 11.

The Scientific Method is a Complete Act of Thought

With knowledge doubling at a faster rate than ever, it would greatly help everyone if they were taught a clear and simple guide for a complete act of thought.

From my research, I believe that such a guide is most commonly called "The Scientific Method" (also called the general pattern of the scientific method). It was developed by many, but most accurately by scientists (an example is SM-14).

The literature contains many formulas for problem solving, creative problem solving, decision making, and other similar terms. While these are "acts of thought," they usually are not complete acts of thought, because the formulas do not usually cover problem origination, challenge of solution, or suspend judgment. They all contain just parts of SM-14.

Wallas, in the *Art of Thought* (1926), gives a formula for the "Art of Thought:" (1) preparation, (2) incubation, (3) illumination, and (4) verification. This has been widely quoted but is too short for a complete act-of-thought formula for teaching purposes.

Dewey's guide to his "analysis of a complete act of thought" has been widely cited. Professor T.L. Kelley of Harvard, in *Scientific Method: Its Function in Research and in Education* (1932), abstracts Dewey's guide in a little different way than most authors, listing the "steps" shown below (he added #8, feeling it was needed). Also shown is a comparison of these "steps" to the stages of SM-14.

Dewey's Complete Act of Thought as Abstracted by Kelley	**Compare To The SM-14 Formula**
1. A felt difficulty.	1. Curious Observation
2. A definition of the difficulty.	2. The Problem
3. A tentative solution.	3. Goals, Planning
4. A mental elaboration of the solution, leading to additional tentative solutions and elaboration, if felt necessary, finally leading to #5.	4. Search — Explore 5. Alternate Solutions 6. Evaluate Evidence
5. The belief that the solution is all right	7. Guess — Hypothesis
6. An experimental verification	8. Challenge Hypothesis
7. An appraisal of the experimental findings leading to acceptance of mental solution and a decision for immediate conductor to rejection and a reinstatement of a felt difficulty, The process is continued until a verified solution which is immediately serviceable is obtained.	9. Reach Conclusion 10. Suspend Judgment
8. A forward look to, or mental picturing of, future situations to which the present solution is pertinent	11. Take Action
NOTE: "A Tentative Solution" was not included as a separate stage in SM-14 as it may occur at #1, in between 1 & 2, at 2 or 3, and normally one or more at 4 & 5.	12. Action Methods 13. Procedural Principles 14. Attributes — Thinking

The Master Method of Knowledge Is: The Scientific Method

Characteristics of The Scientific Method

- **Name** — Denotes stages, procedural theories and the system of science.
- **Purpose and Objective** — To obtain, refine, extend and apply knowledge through problem origination, prevention, solution and challenge of solution. Curiosity, a healthy skepticism, etc. finds the problem.
- **Division of Method** — The master method of all human knowledge methods.
- **Stages** — The general pattern of the major types of mental activity usually aided by physical actions.
- **Sequential** — There are 11 major stages that are sequential and progressive. These stages are arranged in order of usual use but may be followed with flexibly.
- **Repeatable** — Stages are so basic and repeatable that they are not likely to change.
- **Range** — Universal to all nature and human activity.
- **Reliability Factor** — Most reliable of all knowledge methods.
- **Application** — Usually follow techniques, procedural principles and theories, high personal attributes and thinking skills of the research communities. Flexibility or "anything goes" is often essential.

The Value of Method

In the *Concept of Method*, Justus Buchler (1985) refers to the common expression "the power of a method." Every day you constantly use methods and this report will help you better use the power of a method to improve your problem solving ability.

Without method, we are left with chance. Chance is the opposite of method and we would have a very disorganized world without methods and techniques. But, what is "Method"? Unfortunately method is a very ambiguous word. It's so ambiguous that it has been widely misused and misinterpreted in the fields of science and knowledge.

There is no better example of the power of a method than the results produced by the scientific method throughout the development of modern civilization. I did a search of the literature on the value of method. This is what various authors emphasize:

The Advantages of Method

- Organizes our thoughts
- Clarifies our thoughts
- Ends aimless wandering
- Helps ideas gather shape
- Guides us to new knowledge
- Is a repeatable procedure
- Aids in transfer of learning
- Trains for change and innovation
- Uses human potential
- Encourages thinking

The Opposite of Method is Chance

- Haphazard guesses
- Wrong analysis
- Wasted time
- No Solutions
- Confusion
- Wasted energy
- Quick fixes
- Wandering aimlessly
- Misdirection
- Mistakes and errors

The Scientific Method Is A Universal Method for All Domains

It is the master method from which sprang many other methods that were given other names but the stages of these methods are the same. These other methods may have special characteristics, such as being aimed at a certain domain or special purpose. They also may use special, creative, non-logical, logical and technical methods as well as the general ones, but the stages to reliable knowledge are the same. Some authors may name different terms for the stages and present a shorter formula.

Just a few of the other methods that are the same, are the methods of:

- Problem solving
- Creative problem solving
- Scientific management
- Investigation
- Medical diagnostics
- Decision making
- Invention
- Design & Engineering
- Change
- Technological design
- Inquiry
- Research
- Planning
- Scholars
- Operation research

Learn SM-14 and you learn the formula for all of the methods listed above.

This is the Golden Age of Knowledge

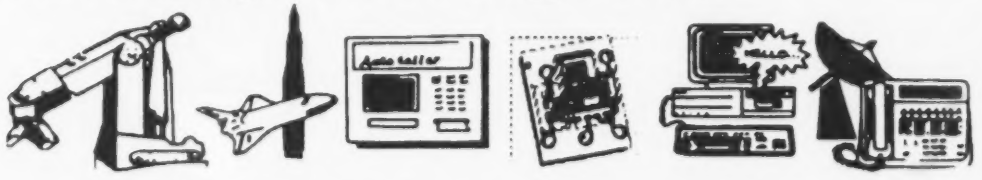
*Estimated years it took for knowledge to double**
1750-1900: 150 yrs 1900-1950: 50 yrs
1950-1960: 10 yrs Since 1960: Every 5 yrs

Projection! By the Year 2020, knowledge will double every 73 days!

We need to study and standardize on the basic method by which we obtain, refine, extend and apply knowledge . . . which is, SM-14.

**Reported at the Teacher Education for 21st Century Conference (1992)*

This Is An Age of Technology Growth



Robots | Space | Automated Tellers | Miniaturization | Talking Computers | Multi-media Communication

High-paying unskilled jobs are disappearing—skilled, innovative, creative, problem solving, adaptable workers are needed!

SM-14 Formula

Pages 8 thru 35 describe the 11 Stages of The Scientific Method and the 3 Supporting Ingredients that comprise the SM-14 Formula.

Help for Originating Ideas for You to Submit to Your Company's Suggestion System

Many companies have suggestion systems, employee involvement programs, quality initiatives and similar programs. Many of these offer monetary rewards.

REMEMBER—even if your company doesn't have a formal plan, submit ideas anyway. Idea originators, problem solvers, good decision makers and those with the entrepreneurial spirit receive promotions, salary increases and become managers or executives.

Suggestions and Ideas to Help You Use SM-14 to Earn More Money:

1. Study this booklet and reflect on its application to your company and to your job.
2. Review the pages on curious observation (Stage #1) and pages 38, 39 and 40 on creativity carefully. These will be of special help in originating ideas that will save your company money or increase sales.
3. Redesign certain pages or add pages to this booklet to make it a tool tailored to your organization's needs.
4. Pages 44 and 45 show a condensed version of "Your Guide and Worksheet for Applying the Complete Method of Creative Problem Solving and Decision Making (SM-14)." You should get my full size pages on this and develop ideas on how and where your company can use these worksheets. For example:
   - Use the worksheets at meetings, training sessions and/or company wide
   - Change the worksheet's format to suit your company's special needs.
5. Recommend use of the rating scale on page 41.
6. Suggest this booklet's use in training courses and general operations as:
   - The most effective and cost-saving habit anyone can have is using the scientific method.
   - It has the most up-to-date explanation of the scientific method available.
   - *Complex Problem Solving* (1991), reports that most managers do not use rational approaches to managerial problem solving.
   - Today, modern management passes the responsibility of decision making further down the ranks. Because of this, the lower ranks need training in decision making skills to handle this new responsibility.
   - World competition requires more innovation and creativity.
   - A company's intellectual capital is just static assets until its knowledge is invested efficiently using the scientific method.

(Stage #1) Curious Observation

Curious observation is the start of the inductive process. Discovery of new problems, ideas, theories, decisions needed, and problem prevention usually begin with curious observation using the five senses: smelling, tasting, hearing, feeling, and seeing. Instruments and tools can be used to help extend these senses.Use your sense perceptions and projections — visually and mentally. Turn thoughts over and over in your mind. Use reasoning, your imagination, and introspection. Being in the right mood, being motivated and sensitive helps! Train your mind to interpret what you see.

Where Does Problem Origination or Discovery Begin?

The answer is "no particular place." Some of the more typical instances are:

- **Things you feel might fill a need** — or that irritate or perplex you.
- **Previous experience** — You have some question or theory to investigate.
- **Need project** — Looking or brainstorming for problems or fields to investigate.
- **Triggered interest** — You decide to investigate as a result of surprise, chance, accidental discovery, observation, illumination, serendipity, reading, experimenting, reflective thinking, or clue. It may also result from a combination of events and things.
- **Assigned, suggested, or thrust** — A specific problem or field to pursue.
- **Recognition of potential trouble** — Preventive investigation required.
- **Solution of one problem** — This often reveals other problems.

What Should You Be Seeking and Be Sensitive To?

- Any of the above. Stay alert. Develop recognition skills. Be persistent.
- Problems worthy of solution, practical to investigate, new fertile fields.
- Ordinary things to be examined in a new way and with new meaning.
- Outside stimulation such as:

Curiosities	Relationships	Experiments needed	Leads
Differences	Disturbances	Unexpected failures	Challenges
Similarities	Intimations	Problematic situations	Surprises
Patterns	Unusual results	"Thorns in flesh"	Opportunities
Obstacles	Comparisons	Listen to others	Suppositions

Curious Observation Also Involves Other Thinking Skills

Evaluating	Visualizing	Imagining	Classifying	Abstracting
Planning	Describing	Questioning	Computing	Judging
Communicating	Interpreting	Conjecturing	Inferring	Measuring

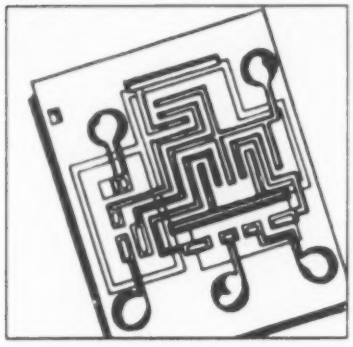
Develop the Attribute of Curiosity

You use it throughout SM-14.

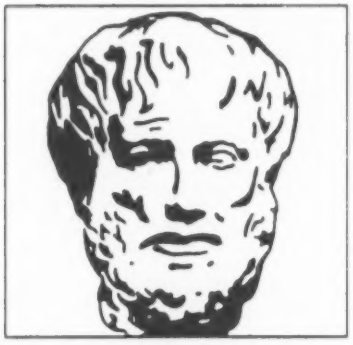
- **Constantly observe** — Ask questions: What, Why, Which, Where, When, Who, How, and If. Visualize what might be. Accept nothing as "fact."
- **Be an innovator** — Cultivate curiosity to find and develop new ideas.
- **Read, skip, and skim** publications and internet for data, and triggers for ideas.

Having found something, continue on now and define the problem. If necessary, gather more information before trying to define the problem. Any solutions you derive, no matter how good, should be considered tentative.

Famous Examples of Curious Observation



In 1969, Ted Hoff revolutionized the microelectronics industry by inventing the microprocessor—the computer-on-a-chip. This made it possible to computerize ordinary tools and appliances. Hoff believes that successful inventors are curious and are always asking questions.



Aristotle's influence and importance as a great scientist was possible because he had the attributes needed. He saw an "order" to the world and applied scientific method to his environment by being curious and making astute observations. He made the statement, "All men by nature desire to know."

The Thinking Skills Associated With Curious Observation and the Scientific Method

The successful use of the scientific method requires the use of numerous thinking skills. On the opposite page and on the other pages of this book, many of these skills are listed. In recent years the term "critical thinking skills" and "higher order thinking skills" have been extensively used. People defining these terms use a wide variety of definitions—some simple, others are very complicated. This creates many teaching problems. It is really an impossible job to say which are simple ones, which are critical and which are higher order.

Also, the word "critical" is associated with criticizing and this causes misunderstanding and scares students.

Many people point out the principal use for thinking is to solve problems and make decisions. Thus, I recommend the use of the terms "thinking skills" and "problem solving thinking skills," rather than "critical thinking skills" or "higher order thinking skills."

Any time thinking skills are taught you should also teach the stages and supporting ingredients of the Master Method of Problem Solving—The Scientific Method.

Students will be much more motivated to learn problem solving thinking skills than "critical thinking skills."

"You cannot find a solution to a problem until you find a problem."

(Stage #2) Is There a Problem?

An idea, problem, decision or tentative theory should be presented in the form of a question because:

- It encourages you to keep an open mind, and thus seek the "truth"and not to prove a statement
- A question is a tool and a guide for productive thinking about problem solving and investigation of a new subject.

Look at Problems as Challenges and Opportunities

Develop a passion to solve! Define the problem carefully so you know what direction to take.

- It prevents you from wasting time and may indicate whether it is solvable.
- A wide enough (but not too wide) definition allows for alternate solutions.
- "A problem properly defined is often half-solved."

Things to Help You Define and Understand the Problem Properly

- Consider purpose, goals, criteria, and significance.
- Ask: What? Why? Which? Where? When? Who? How? If?
- Know the domain in which the problem falls.
- If you don't know enough about the subject, you may have to loop ahead to Stage #4 and search for information to help define the problem.
- If problem was assigned to you, review its origin. Read and reread it.
- Define the problem's deep (or basic) structure. Juggle the elements.
- End with a question that is brief, clear, purposeful, and thought-provoking.
- Plan to revise the definition as your research proceeds. Read and reread it.
- Things to write down, consider, or do about the problem:

Characteristics	Unknowns	Make concept map
Attributes	Symbols	Draw pictures
Critical issues	Concepts involved	Use models
Analogies	Separate elements	Quantitative aspects
Use imagery	Make idea tree	Other representations
Challenge assumptions	State problem another way	

Tentative Solutions — Keep an Open Mind

Be alert for any possible solutions. Even if enthused with any solutions that arise, consider them tentative until you use Stages #4 through #6.

These Basic Principles Still Hold in Problem Solving

Rene Descartes in *A Discourse on Method* (1637) advised:

- Never accept anything for true which you do not clearly know to be such.
- Divide each difficulty into as many parts as possible for it's adequate solution
- Commence with the simplest and easiest to know
- Do a complete review so nothing is omitted

Famous Examples of Is There a Problem?

Thomas J. Watson recognized a "felt difficulty" and developed IBM into a leader in the field of computer technology. This is an example of how the innovative and creative efforts of one man, his organization, and related industries have added trillions of dollars to our gross national product.

What? Why? Which? Where? When? Who? How? If? Thomas Edison was constantly on the alert to find and solve problems. He held more than 1,000 patents, including famous ones for the electric light, phonograph, movie projector—adding trillions of dollars to our gross national product.

What Are The Sciences Today? This Is a Problem that Needs Defining

A good example of a need to define is determining "What is a science?"

Years ago when the sciences were referred to, it was understood that people were referring to the domains in the natural sciences such as: physics, chemistry, astronomy, geology and biology.

Nowadays, you read about social sciences, engineering sciences, decision sciences, management sciences and others. Because we are now learning in all domains more intensively and at a faster pace, the 21st century will produce other areas developing into "sciences." The natural sciences have led the way and set the standards.

To really be a "science" there must be:

- A group of practitioners in a domain or sub-domain with relevant professional organizations and publications and following the scientific method in their research and when peer reviewing.
- At the action stage, peer review for their research. The phenomenal results of scientists in the natural sciences has been greatly aided by their peer reviewed publication system. Articles based on use of the scientific method are first screened for accuracy by reviewers. After, corrections and final approval, articles are published for fellow practitioners to challenge, test, approve, use, etc.
- As a group, an attempt must be made to build up a reliable organized body of knowledge in their area of specialization.

"You stop being good when you stop getting better."

(Stage #3) Goals And Planning

GOALS — End results you want to achieve in solving a problem

- Goals must be realistic, flexible, and subject to change.
- Put goals in writing. This helps analyze priorities and avoid carelessness.
- Consider methods, processes, technologies, systems, strategies, and formulas needed.
- Set target dates for stages and completion.
- Learn to process information efficiently.

In considering goals, think about:

Real purpose involved	Sub-goals	Perfection not always needed
Where goal is leading	Criteria to use	Revising as required
Your basic needs	Values to use	Long & short term goals
Future consequences	Time/budget	Measurability/specific end

PLANNING — How to reach your goals. Always think and plan ahead.

- Planning speeds solution — Avoids wasted time and effort. Put plans in writing.
- Develop plan to use today's huge computer databases of information.
- Abstract and outline theories & basic principles involved in the problem.
- Plan must be flexible — When working on complex, ill-structured problems, things will change frequently. Thus, don't start with too detailed a plan.
- Plan for overall solution — Preliminary program for each ingredient of SM-14.
- At start of work on each ingredient, prepare revised program for this ingredient.
- Compile tentative solutions — Know the scope of areas you are going to search.
- Experiment and test — Watch for methods to test tentative solutions.
- Similar problems solved before — Review records to benefit from experiences.
- Intuition and insight — Use to save you time and aid direction.
- Build your team — Involve them in goals and planning.
- When solving ill-structured problems you must tolerate ambiguities.
- Plan how to control constants and variables.

A few other things to consider in your planning:

Keep log book	Start with easiest sub-problems	Algorithms
Time, budget, priorities	Utilize sketches and diagrams	Alternate plans
Methods, strategies	List factors contributing to solution	Thinking aloud
Resources available	Criteria to meet or establish	Models, analogies
Checking feedback	Supplies, facilities, instruments	Trial and error
Challenge assumptions	Build up your library and files	Watch for clues
Impact on society	Approvals and decisions of others	Emotions, stress
"Anything goes" theory	Laws, licenses, legalities, patent search	Anticipate troubles
Apply innovations and creativity	Assignment of responsibilities	

Sub-Problems

An experienced problem solver soon learns that you should break any complex problem down, separate and solve the sub-problems and sub-sub-problems before attacking the main problem.

Famous Examples of Goals and Planning

Anthropologist and author Margaret Mead had a lifetime goal to learn about human nature. Her research answered basic questions about human personality. Her plan of action included college study, specialized training, and living with primitive societies.

It was due to careful planning that Gregor Mendel was successful in his experiments with pea plants which provided new insight into the laws of heredity. His goal was to find out how characteristics of parents are passed on to offspring.

Problem-based Learning — Great Goal, But Poor Planning

There is a growing movement to teach law, medicine, engineering, business and other subjects by Problem-based Learning. In many instances those sponsoring this type of learning fail to:

- Include any formula for the stages and ingredients of the scientific method, which is the master method of problem solving.
- Or use inadequate formulas—such as offering one that is too short.

This situation is an example of the excellent goal of teaching problem solving, but poor planning and analysis of what is needed to accomplish the goal.

If you do not teach any formula when using problem-based learning programs, you fail to a great extent getting transfer of learning. Centuries of use of the scientific method have shown there are basic stages to reliable problem solving. SM-14 is a well-researched formula. After reviewing hundreds of other formulas, I have found SM-14 to be the best suited for problem solving.

SM-14 becomes a strategy that guides you in solving complex, ill-structured, real world problems. It has evolved over the centuries since Galileo's time. Another basic principle is that one learns to become an expert by solving a large number of problems, following a formula such as SM-14.

"Defective problem solving is the cause of all disorders in the world."

(Stage #4) Search, Explore and Gather The Evidence

This is the heart of problem solving. You start to search everywhere, explore all angles, leads, clues, and sources of information. Pick out the basic principles of the material you read, see, or hear. Gather all the evidence that will help you solve the problem, always trying to use innovation and creativity, thus building your list of possible tentative solutions. Learn how to process information productively. Put your thoughts in writing.

Search Your Mind for Tentative Solutions

Before loading your mind with data, other people's opinions, and so-called "facts," list all possible tentative solutions you can think of for your main problem and any sub-problems. Reasons: (1) Provides you with direction and scope in your search.(2) Enables you to utilize imagination before being influenced by prevailing thoughts and theories.

Review Plans and Prepare Your Program

- Keep log
- Build files — use all resources
- Enlist team of advisors
- Prepare broad literature search
- List any known sub-problems
- Read about How-To-Research

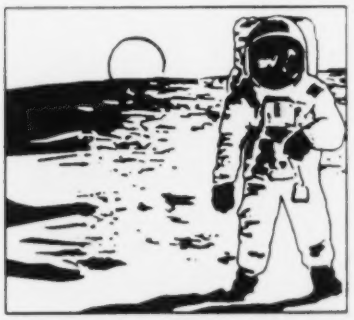
Possible Methods, Processes, Strategies, Technologies, and Systems

- Redefine problem as needed
- Draw inferences
- Watch for patterns
- Classify
- Make associations
- Discard the irrelevant
- Find inter-relationships
- Simulate or improvise
- Anticipate the unexpected
- Sampling and statistics
- Measurements
- Work backwards
- Algorithms
- List attributes of subject
- Utilize routines
- Group brainstorm
- Imitate nature
- Utilize computers
- Spot key factors
- Solve sub-problems first
- State problem another way
- Compare to other problems
- Abstract basic principles
- Be flexible — vary your attack
- Watch for leads, clues, hints
- Control variables — causes and effects
- Watch for surprise discoveries
- Plan experiments — be curious
- Interpret data — use all data
- Trial and error
- Look for similarities and differences
- Visualize — watch for "oddities"
- Logical reasoning and speculation
- Use checklists, models and analogies
- Use qualitative and quantitative analysis
- Use sketches, trees, concept maps
- Use flow charts, spreadsheets, symbols
- Look at problems from a different angle

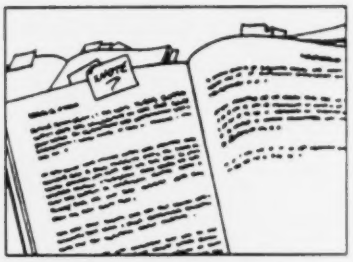
Develop Your Reflective-Directed, Speculative Thinking

Talk to yourself in both language and images . . . silently or aloud. Daydream with your thoughts directed to thinking about the data you reviewed. Think reflectively while searching and while doing routine things such as exercising. Jump back and forth among logical, critical, imaginative, and wild thinking.

Famous Examples of Search, Explore and Gather The Evidence



Because of searching, exploration, and information gathering, the teams of NASA scientists, engineers, technicians, and astronauts solved the complex problem of landing man on the moon. The dream became a reality on July 20, 1969, when Neil Armstrong took man's first step on the moon. A triump for the scientific method.



In searching for information to include in this booklet, I used over 15,000 Post-it Notes™ to mark helpful pages. Dr. Art Fry invented 3M's Post-it Notes™ to satisfy a felt need to efficiently mark pages. Experimenting with a special adhesive developed by 3M's Dr. Silver, Dr. Fry developed his idea into a successful product.

The Internet Facilitates Gathering The Evidence

The Internet has caused a boom in the availability of data, information, and knowledge and has already changed our lives in many ways and will continue to do so. Remember that computers and the "Web" resulted from scientists and technologists, following the scientific method.

Users of the internet are going to have to know how to use the scientific method for these reasons:

- The flood of available data, information and knowledge frequently requires evaluation of its reliability — the method to verify reliable knowledge is the scientific method.
- It is the method of change — therefore will be needed more than ever.
- The method of applying all this knowledge is again the scientific method.
- For the sake of your reputation and the good of society, knowledge you put on your "Web" site should have the reliability of having been gained by the scientific method.
- Improvements to computers, the web, software etc., will require the use of the method of invention — that is the scientific method.

"Be sure to double-check everything you read on the Internet."

(Stage #5) Generate Creative and Logical Alternative Solutions

Logical Solutions (or Trial and Error)

You can solve many problems the same way many great discoveries have been made-by trial and error or by using gradual, systematic, steady, analytical, judicial reasoning and logic. You gather the data and fit it together. What was a puzzle falls into a logical order. Aha! You have a discovery or solution to your problem. Most importantly, however, problems are solved by the leap of the imagination, as often the solutions are infinite.

Innovative Solutions

Search out other people's ideas. Use as they are or adapt for your particular problem by combining reflective thinking and your creative abilities.

Creative Solutions — Use of Imagination

Creativity is usually described as taking two existing ideas and combining them into a new and better idea. It is also termed divergent thinking, lateral thinking, insight, intuition, flash of inspiration, innovation, ideation, guided design, generative thinking, productive thinking, etc. Successful people have also found imaginative thinking helpful in deciding what ideas or directions ***not*** to use or consider in detail. *There is not enough space to discuss all the ways to generate alternative solutions. Below are what I consider to be the most important methods (see pages 38 to 40).*

- **Reflective Thinking** — You search, explore, follow leads, gather pertinent data, information, basic principles, concepts and use reflective thinking. You can also use rest-illumination or rest-insight. You load your mind with subject data — then rest — then ***start*** thinking about your problem again in a relaxed manner.
- **Triggers** — Things that stimulate your mind's store of stocked memories and cause recall and new train of thought. It's best to load your mind with data pertinent to your current problem. It is the prepared or loaded mind that can best be triggered. At that point, you then:

Experiment or visualize	Brainstorm
Have discussions-pick minds	Browse through a store
Attend conferences and exhibits	Search your files or periodicals
Use a computer program	Trial and error procedures

While you are doing all these things, you are reflecting on your problem as you acquire more information. Then, EUREKA — suddenly ILLUMINATION comes — or more gradual insight climaxes! Something has triggered your mind and you have an idea, lead, discovery, or a tentative solution. This may be a small or very big idea.

Most Productive of All

Read, skip, and skim through a wide variety of Internet sites, magazines, newspapers, and books. These are the nation's idea banks which are filled with things to trigger your mind. Visit your library where there are hundreds of magazines on display. Books on creativity and school courses usually fail to emphasize the value and importance of using triggers.

Famous Examples of Generate Creative and Logical Alternative Solutions

Karl Pearson, in his famous book, *The Grammar of Science*, published in 1892, stressed creativity as a separate feature of "the scientific method." His exact words were "the discovery of scientific laws by aid of the creative imagination." He also advocated the scientific habit of mind for solving all problems of life.

Alex F. Osborne, author of *Applied Imagination* and founder of the Creative Education Foundation, and Dr. J.P. Guilford made a tremendous contribution to the popularization of interest in and development of the techniques of creative thinking—urging generating alternatives. These efforts spawned many books and seminars.

Logic and Creativity vs. Exercise Problems

Exercise problems, textbook problems, puzzle problems, and game problems are used extensively in schoolwork and tests. While usually referred to as "problems," they really should be called what they are—one of the above names. Schools are teaching the methods, techniques, formulas, strategies and domain-specific information needed to solve them.

While they serve a useful purpose, they are not sufficient preparation for the everyday, real-world problems that we must face.

Real World Problem Solving and Decision Making

These require more real world logical reasoning and the use of creative thinking and methods. The teaching of these in our schools needs to be increased.

Paul D. Hurd, in an article in AAAS's book, *Scientific Literacy* (1989), reports that, since 1983, over 300 reports on the condition of education in the United States have been issued. He states:

> *Consensus also exists among the reports' goal for science education. The goals are to develop the abilities to (a) solve problems encountered in the workplace and in the conduct of personal life and civic responsibility. . .*

"More use of the scientific method will benefit everyone—spread the word."

(Stage #6) Evaluate The Evidence

By now you should have a list of tentative solutions that are candidates for your educated guess or hypothesis. It is also the stage for experimenting and testing. The final choice is often called your working hypothesis and will be your Stage #7.

Starting guides to consider before working on each ingredient

- **Problem** — Should it be redefined or reframed?
- **Goals and planning** — Any changes? Any new leads or clues? Planning ahead?
- **Goal referencing approach** — Where you started, are now and still need to go.
- **Looking back** — Have you been using the right attributes, methods, strategies, technologies, plus curious observation? Have you consulted your advisor? Have you had a team meeting? Are you keeping your log up-to-date? Being on the right path is important!
- **Are you using innovation, creativity, watching for surprises?** Are you alert to clues and leads?
- **Are you putting thoughts and ideas into writing?** Using all available resources?

Evaluating Your Tentative Hypotheses

- If data on any of these hypotheses is insufficient, gather additional information.
- Check against any list of criteria, formulas, and routines you have established.
- It may be helpful to read the information on Stage #7 to familiarize yourself with the characteristics and traits your working hypothesis must have.

Also, read Stage #8 to alert you as to how it will have to be challenged.

Tests, Experiments and Other Methods, Strategies, and Techniques of Evaluating

Logical reasoning	Measuring	Mathematical solution
Consult literature	Surveys	Independent lab test
Collaborators	Interviews	Expert opinions
Controlled experiments	Modeling	Concepts correct?
Dis-confirming test	Graphs	Improvisation
Data base reliable?	Sampling	Disqualifying
Consider consequences	Speculation	Make predictions
Statistical analysis	Simulations	Challenge assumptions
Design special instruments	"Live It"	Computer testing
"Anything goes" theory	Visualizing	Need to ripen more?

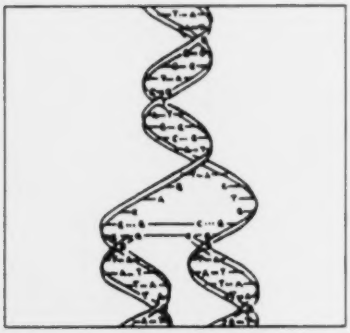
Chart Your Solutions to Weigh the Evidence

Be more careful and make your choice. Criteria can be graded by as many facets, characteristics or angles, as you desire. You can have individual charts or a joint one. Tailor headings to fit your problem.

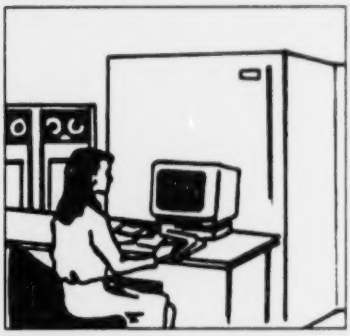
Possible Comparison Chart

Tentative	Test Results		Suitability		Feasibility		Acceptability	
Choices	#1	#2	#1	#2	#1	#2	#1	#2
Solution A	Against	For	30%	Okay	60%	Okay	50%	90%
Solution B	For	Against	50%	No	80%	No	90%	20%

Famous Examples of Evaluate the Evidence



After evaluating all the evidence, biologist James Watson and biophysicist Francis Crick solved one of nature's greatest puzzles — the structure of the DNA molecule the genetic "blueprint" that dictates the traits which living things inherit. They earned a Nobel prize for this discovery in 1962.



Herbert A. Simon, Nobel Laureate, and his associates researched the human problem-solving process. Through evaluation of the evidence, they arrived at the hypothesis that a great variety of problems could be solved by use of a computer. Dr. Simon's books contain a wealth of evidence on problem solving and artificial intelligence.

Evaluate Carefully, But Remember — Perfection Is Not Always Possible

Time, money, emergencies, importance, practicability and constraints on human thinking often mean we can't be thorough, even though we would like to be.

Thus we must often settle for "good enough." Similar descriptions are tolerance of ambiguity, aspiration level, most optimum not needed, satisfactory versus optional standards, adequate for problem, risk within reason, bounded rationality. The general principles in considering all your efforts:

Accept uncertainty of solution
Perfectionism is not always affordable
"Truth" may not exist
Rate: Good — Better — Good enough
Consider community "standards"
Precision — important in science
Waste no time on little differences
No excuse for sloppy work
No single best solution may exist
No better action to take

A good intuitive base of actual experience or reading of other peoples experience will be of great value in making a quick decision on matters of minor importance, but remember if you make decision on wrong "facts," what follows are wrong solutions.

Learn to evaluate as — good, better, good enough, or not good enough — and search for further data keeping in mind costs *vs.* benefits.

"Struggle is the essence of life — true happiness comes from being useful."

(Stage #7) Make the Educated Guess (Hypothesis)

Review the starting guides at top of Stage #6 on Page 19. Your educated guess—technically, the hypothesis—is a proposed solution to the most recent definition of your problem. It is your choice of the most-likely-to-be-successful solution from the list of contending ones, which you evaluated.

Terminology, Definitions, and Descriptions:

- **The hypothesis is often called "the educated guess,"** because scientists have long recognized the difficulty of arriving at the real "truth."
- **Working hypothesis** is a term used to describe this proposed solution. It is only a "candidate for truth," as it must be challenged under Stage #8.
- **A hypothesis** would be a theory of nature in the natural sciences. In other fields, it could be a decision, plan, diagnosed illness, idea, design, invention, etc.
- **More than one hypothesis (hypotheses)**—you might propose more than one solution. Problems in the social sciences often require several hypotheses.
- **A perfect solution is seldom obtained** in solving complex problems.
- **Inductive reasoning** has helped reach your hypothesis. See Ingredient #14.
- **Valuable even if proven false**—a hypothesis will often be wrong but may lead to a discovery, a new field to explore, or a modification of the hypothesis

The Characteristics or Traits of a Hypothesis

These are desirable but not always essential or possible;

Relevant and adequate	Adds to existing knowledge
Verifiable or falsifiable	Consistent with existing knowledge
Logically possible	In simplest terms possible
Conducive to further inquiry	Answers defined problem

Predict Consequences

Now that you have chosen a hypothesis, you must make predictions of why and how something will occur, based on the accuracy of your hypothesis. Testing these predictions helps you challenge, justify, or falsify your hypothesis in Stage #8. Then others can try to do so—after, you take action and communicate at Stage #11.

Types of consequences and predictions:

- If change is made, consequences will be . . .
- If experiment is made, it will show . . .
- If reasoned out, results will be . . .
- If cost and benefits are computed, they will show . . .
- If survey or interview is conducted, it will show . . .
- If mathematical computation is made using certain data, it will show . . .
- If a model is made, this will happen . . .
- If a computer simulation is programmed, it will show . . .
- If a scenario is prepared, enumerating all possible results, it will be . . .

Famous Examples of Make the Educated Guess (Hypothesis)

Simon Bolivar—Five republics of South America term him father of their independence. He faced the problem of how to free his country (Venezuela) from colonial oppression. When one hypothesis failed, he generated another and another until he finally succeeded.

Benjamin Franklin is well known for his famous kite experiment in which he explored the nature of lightning. He formed a hypothesis, and in 1749 performed his dangerous kite experiment. Franklin concluded that lightning is an electric charge.

This Technology Era Requires Technical Working Hypotheses

You often hear the term "Science & Technology" but often Technology is lumped under "Science." Regardless, the method of technology is the same as the method of science. You use the scientific method in originating, arriving at a working hypothesis, and finally in solving technology problems as well as when applying technology.

The Technology Panel of AAAS' Project 2061, in their 1989—Phase I Report, states:

Technology education should emphasize problem solving. The posing and solving of problems, increasingly complex as students move from kindergarten through the twelfth grade, will enable students to develop techniques that are vital to living in a technical world of diverse cultures and technical status. The problems and their solutions may be technical experimental, mathematical technical-social, or value-laden. Designing alternatives to circumvent problems and learning to deal with options are also important techniques . . . Observation, measurement, and analysis are universal tools of technology . . . Intelligent observation is crucial to invention. . . .

"The law that only problem-solvers survive is as inflexibly relentless as the law of gravity."

(Stage #8) Challenge the Hypothesis

Usually the stage for final experimentation and testing.

Review the starting guides listed at the top of Stage #6 on Page 19.

- **The degree of challenge** to your hypothesis will depend on the type of problem and its importance. It can range from just seeking "a good enough" solution (but not a haphazard or lazy one) to a much more rigorous challenge.
- **To accommodate a broad range**, Dr. Crooks used the term "Challenge." Most formulas for the scientific method use the terms verification, justification, refutability, validity, falsification, testing the theories, experimentation to test and many similar terms indicating that the hypothesis should be challenged.

Experimenting, Testing, and Challenging the Hypothesis

- **Falsification:** Sir Karl Popper advocates trying to prove a hypothesis to be false rather than trying to prove it right. This may save time and avoid bias.
- **Verification:** Many disagree with his falsification theory and believe various methods should be used to verify the hypothesis.
- **Who Is Right?:** This is an extremely controversial and difficult question to answer. Try both approaches. Gather evidence for and against your hypothesis.
- **Predictions:** Use to challenge your hypothesis. Under Stage #7, you made certain predictions that resulted from your hypothesis. The way to challenge your hypothesis is to try to prove these false, probably true, or supported.
- **Modify Your Hypothesis:** In testing your predictions, if you find something wrong, backtrack to Stage #7, modify your hypothesis, and change your predictions. If it fails completely, backtrack to Stage #4 or #5. We learn from failures.
- **Control Variables:** Vary one thing at a time—make notes on each.

Repeatability of Your Tests and Experiments

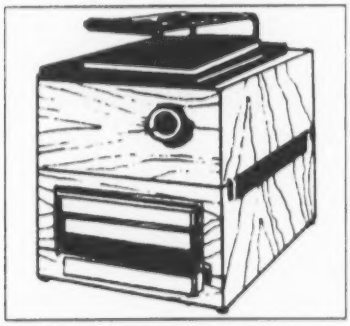
For your hypothesis to be accepted by others, your testing results must be able to be repeated by you and those who will want to verify your theory.

Log all tests	Results must fit known "facts"	Be accurate
Report unknowns	Experiments must be complete enough	Review data
Control stress	Results must be consistent	Be honest
Try for simplicity	Watch for "bugs" that spoil tests	Get advice
Use sampling	Use statistical verification	Use math

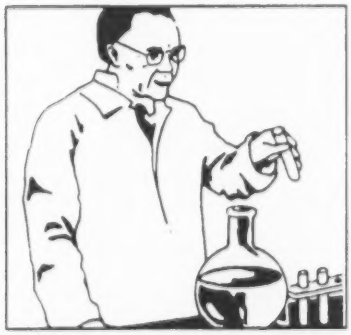
Other Suggestions

- **Fault Tree** — Prepare one on how your hypothesis or tests can possibly fail.
- **Alternate Hypothesis** — Be curious, observant and alert for a better hypothesis.
- **Dis-Confirming Evidence** — Don't ignore, follow up. Be critical.
- **Competing Hypotheses** — Verify by eliminating these, but remain flexible.
- **Some Hypotheses Not Verifiable** — When in social sciences, geological fields, etc.
- **Consequences and Contingencies** — What results from your hypothesis?

Famous Examples of Challenge the Hypothesis



While working as a patent attorney, Chester F. Carlson decided to design a fast, easy, and inexpensive way to make copies of text and tine drawings. After challenging several hypotheses, he successfully produced the first xerographic copy in 1937. This invention added billions of dollars to gross national product.



Dr. Percey L. Julian, by synthesis of the drug physostigmine, brought the healing drug cortisone within the reach of millions. He defeated the challenge of a British rival and proved his theory. Dr. Julian's appointment to head The Glidden Company's research marked the turning point in acceptance of black scientists in the United States.

Predicting and Prevention

Prediction has always been a big feature of the scientific method, whenever it is used. Once a working hypothesis is arrived at, you make predictions to challenge what will happen if they are correct. From them, you can do tests and experiments to determine whether these are correct or false.

Forecasting the Future

Forecasting the future is extremely difficult. Plain guesses and gut intuition are often used but not very reliable. Actually there is no reliable method. But, of all the methods the most reliable one is to follow the stages of the scientific method.

Prevention

While the scientific method is famous for its use in discoveries, it is also the method of prevention.

It is not logical to wait till problems develop or till decisions have to be made after trouble occurs. Therefore, the use of curious observation (stage #1 of SM-14) must also be used to look for things that may happen and that need to be prevented.

The importance of prevention and forecasting are more reasons why every one should learn and be taught the scientific method.

"The solutions of today will be out-of-date tomorrow."

(Stage #9) Reach a Conclusion

Begin by reviewing the starting guides listed at the top of Page 19. You have challenged your working hypothesis. Now comes the conclusion. If your hypothesis is partially wrong, backtrack, modify, and then challenge again. If completely wrong, you backtrack and take another path.

We learn from our failures. Do not become discouraged! Even great men and women are frequently wrong. If your hypothesis passes the important tests—**you have reached your conclusion!**

Your Conclusion Should Be (Among Other Things):

- broad enough to fit all acceptable data;
- limited enough to meet special exceptions,
- consistent when tested by you (and others) again and again,
- seldom extended beyond the evidence,
- suitable to base a report on, if one is scheduled; and
- an answer to the problem, as you have finally defined it.

Take a Good "Look Back" to Re-evaluate Your Investigation

Gathered all the evidence?
Experiments properly performed?
No fraud by teammates?
Variables properly controlled?
Any other possible goofs or errors?
All consequences considered?
Any conceptual blocks?
Ethical considerations?
Overall accuracy good?
No bias has crept in?
No wrong assumptions?
Anything overlooked?
Feedback?
Environment considered?

Things to Do Now (Preparation for Stage #11—Take Action)

While everything is fresh in your memory, think about and prepare notes on:

- **Limitations.** If there were any limitations on your efforts or results in defining the problem, the search for evidence, or the challenge phase, include them in preparation for reporting under Stage #11.
- **Speculations and Looking Forward.** If you were doing a project that advances the knowledge in your field, you might want to prepare some speculations or predictions even beyond what the evidence supports. Label as speculations.
- **Research Method Recommendations.** Based on your experience, make recommendations, give warnings, hints, and references to those who may try to challenge, verify, or falsify your conclusions.
- **Conclusion Recommendations and Presentation.** If you work on a decision problem, plan, management problem, etc., you may want to prepare recommendations based on your conclusions to submit to authorities.

Intelligent Compromise: In problem-solving or decision-making, in the "inexact" social sciences, etc., your conclusions may have to be an intelligent compromise. The solution of any problem (and its acceptance) depends on good human relations. Consult those who will be affected by your conclusions

Famous Examples of Reach a Conclusion

Curious to know what ingredient made uranium ore so powerfully radioactive, Marie Curie gathered the evidence. In her search and exploration, she tested all known chemical bodies, discovering two new elements: radium and polonium. For these discoveries, she was awarded the Nobel Prize in Chemistry, 1911.

Albert Einstein's conclusion about the theory of relativity has been tested and has never been disproved. Two famous quotes of his: "Imagination is more important than knowledge, for knowledge is limited." "The formulation of a problem is far more often essential than its solution, which may be merely a matter of mathematical or experimental skill."

US Supreme Court's Conclusion About The Scientific Method

In the 1993 US Supreme Court decision, *Daubert v Merrill Dow Pharmaceuticals Inc.*, the court reviewed the definitions of scientific evidence, scientific knowledge, scientific validity and good science. As part of this case, the American Medical Association, et al, filed an Amicus brief in support of the respondent and stated:

> *"Scientific Knowledge" within the meaning of Rule 702 is knowledge derived from the application of the scientific method.*

As part of its decision, the Supreme Court declared:

> *"But in order to qualify as "scientific knowledge" an inference or assertion must be derived by the scientific method. Proposed testimony must be supported by appropriate validation — i.e., "good grounds," based on what is known."*

Therefore, the official position of the US government is that the scientific method exists. This decision clearly indicates to all agencies of the United States that the scientific method exists. For proper justice to be rendered, our attorneys, judges and the general public, from whom jurors are chosen, should be familiar with the scientific method. It should be thoroughly taught in all our schools.

"Skills are more widely applicable than knowledge and information."

(Stage #10) Suspend Judgment

Throughout a project, a good researcher has an open mind and a skeptical, but practical, attitude, always suspending judgment to some degree.

You have spent a lot of time and effort to reach a final conclusion, but now you must change your attitude and suspend judgment. Do not "fall in love" with your final hypothesis. Watch for other concepts or trains of thought.

An excellent description of this stage was given by Dr. Crooks in his 1958 paper (mentioned on page 28). Discussing the ingredient of "Suspended Judgment," he stated:

> *"The investigator must stick to his conclusion until it is proved wrong, but he must keep an open mind and be ready to accept new evidence or speculations if sufficiently convincing. He is therefore ready to adjust his own views if they are untenable.*
>
> *This is the crux of the scientific attitude: an abiding faith in some view or opinion allied to a healthy skepticism; a questioning challenging doubt of new ideas, but a mind definitely open to new ideas.*
>
> *This sounds conflicting, but it is not. The true scientist or the citizen with a scientific attitude is no bigoted stand-patter, but he is no wishy-washy turn-coat either; he does not go chasing after strange idols just because they are new, nor does he condemn another idea just because it is old.*
>
> *He realizes that truth is not simple, that knowledge is forever growing, and that opinions thought correct today in the light of present knowledge may be thought incorrect tomorrow because of new discoveries or the projection of new ideas."*

IMPORTANT!

There can be great flexibility in the order in which SM-14 stages are utilized. Stages are numbered and in their ***usual order of use***. Utilizing the stages in solving a problem, you may often:

1. Skip ahead
2. Backtrack
3. Stall
4. Loop ahead or back
5. Combine two or more ingredients
6. Use various combinations

Never refer to the stages as steps or rules! However, in many of the methods used under the stages, there may be steps or rules to follow.

Develop Your Communication Skills

Educators and employers increasingly stress the importance of verbal and written communication skills. There is a movement to teach writing across the curricula. Develop proficiency in the following:

How to write a report	Spelling and punctuation	Public speaking
English grammar	Subject terminology	Vocabulary
English composition	Communication Knowledge	Self confidence

Famous Examples of Suspend Judgment

In December 1967, Christian Barnard performed the world's first human heart transplant in Cape Town, South Africa. Before reaching a conclusion that the operation was successful, Dr. Barnard suspended judgment in order to observe and gather more information.

Suspend judgment if you think the Japanese are only imitators. Japan made great strides by just being innovative. Learning to be a good innovator is the first step on the road to creativity. Today, Japan is quickly becoming more creative.

Keep Your Mental Process Open

Even after reaching your conclusion, keep your mind open and thinking. Charles R. Foster, in *Psychology for Life Today* (1966, 16th Printing) describes our thinking process:

> *"In psychology the term thinking is usually applied to that type of mental process which we identify as problem solving. There are, however, a number of kinds of mental activity, which are sometimes referred to as thinking.*
>
> *There is a general "stream of consciousness" of which we are aware during all or most of our waking movements. A succession of ideas, images, reveries, and associations streams through the mind, and we are aware, if we stop to contemplate it, of this activity of ours. In most present-day psychology, however, when the subject of thinking is under consideration, the phase of it which has to do with reasoning or problem solving is of chief concern. Hence, in this chapter we are confining our discussion to the psychology of thinking as problem solving.*
>
> *We are omitting any consideration of thinking as reverie, or as daydreaming in the usual sense of the term — we are thinking mainly of what occurs, in our mental processes as we deal with the everyday problems of life."*

The Fuzzy Principle:
"Everything is a matter of degree."

(Stage #11) Take Action

Prepare for Action!

This is often called the "gaining acceptance stage."

- Review your plans and goals. Have the courage to act now.
- Innovation and creativity can help immensely. Read how to present, sell, and gain acceptance of your concluding hypothesis. Get other opinions.
- Give proper credit to your team, reference sources, and associates.
- Report the social and ecological effects of your hypothesis.
- Look ahead — mention possibilities that others may not see.

The Action You Take Depends on the Nature of Your Investigation:

- **Scientific theory, process, discovery** — You will usually prepare a report using the IMRAD format of *Introduction, Method, Results, and Discussion*. This can be submitted to a scientific journal for peer review and possible publication. Other possibilities:

Publish book	Report to superiors	Report to project sponsors
Apply for patent	Sabbatical leave	Enter in Science Fair
Publish pre-prints	Summer school	Present paper at meeting
Press release	Inform colleagues	Commercialize process

- **Invention, technological design, new product idea** — Do any of the above; make a model, apply for a patent, do market research, make an effort to gain acceptance, and sell or merchandise the product.
- **Decision, plan, dispute, social science problem, geography or history research, the arts** — Do any of the above. Implement a solution, if possible. Prevent future problems.
- **Recommendations** — If submitted to authoritative body, wait for review. If modified, rejected, or partially accepted, you will have to coil back to one of the earlier ingredients and work ahead again.
- **New problems** — Solving one problem often leads to new problems. Maybe you made some surprise discoveries or saw opportunities for research in new areas. Consider all consequences — make predictions. Offer clues and leads. Mention in your report.
- **Obstacles to acceptance** — Many eventually highly-successful hypotheses have had a very rough road to acceptance. Others have won immediate popularity. Thus, your action may have to include overcoming these obstacles that cause people to reject new things:

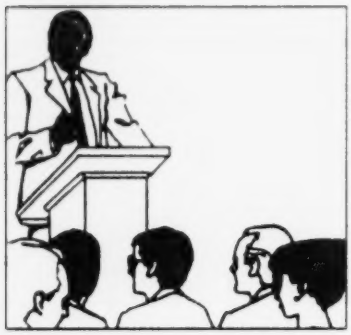
Jealousy	Resistance to change	Organized skepticism
Bias	Loss of prestige	Wrong assumptions
Financial loss	Not enough proof	Poor reasoning
No market	Authoritarianism	Won't admit wrong

- **Aids to acceptance** — All through your problem solving you must think of ways to gain acceptance. Review these and investigate any other ideas. Now develop and apply them. Use your communication skills. From start to finish, we use curiosity. You must also evaluate your action — look back! Are results as expected? Must you modify anything? Use retrospect.

Always the Inquiring Mind

Examples of Take Action

Tribute to All Our Scientists



This booklet is dedicated to Dr. Kenneth B. M. Crooks (1905-1959) whose article "Suggestions for Teaching the Scientific Method" inspired me to write it. It is also dedicated to the past and present members of the intellectual community from whose books and publications I have compiled most of the information in this pamphlet. So many works have been reviewed, it is not possible to credit individuals. They used their many personal attributes productively. Thanks to them all!

Let us also remember the millions of scientists, researchers, inventors, and other problem solvers who have displayed curiosity, persistence, creativity, and honesty in their work. We need to thank them for their contributions to world knowledge and for trying to make this world a better place in which to live.

Action Is Needed to Standardize on A Formula for The Scientific Method Such as SM-14

To the extent that the scientific method is taught in our schools, numerous formulas are used. While many are reasonably good, most are too short. This variety is very confusing to students and teachers.

I recommend that a well-researched formula that has been put through all the stages of the scientific method such as SM-14 be officially adopted as the standard one. This formula, in addition to covering the method of science, is also the same for general problem solving, decision making, operation research, method of inquiry, invention, medical diagnostic and many others. Thus, it would be of a wide benefit to every one who learns it.

This is especially important as all signs indicate the scientific method will, in the future, be extensively taught in all grades and across the curricula.

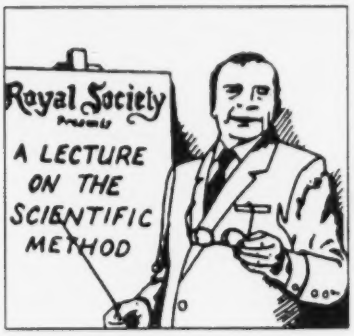
The US Supreme Court should adopt a standard formula also, to aid in identifying how expert witnesses are using the scientific method in their testimony.

Until such time as an official body adopts a formula, I recommend that all authors, teachers, etc., use the SM-14 formula — it is not copyrighted.

"Chaos is ended only by methods — use SM-14."

Supporting Ingredients to The Scientific Method (SM-14)

Supporting Ingredients:



The scientific method is often said to represent the system of science. Frequently formulas for the scientific method are condensed versions of the method. In the SM-14 formula, a more complete formula is presented. To make the formula more suitable for teaching purposes and people to understand the method of science, supporting ingredients have been included in the SM-14 formula. They are:

- **#12 — Creative, Non-logical, Logical and Technical Methods**
- **#13 — Procedural Principles and Theories**
- **#14 — Attributes and Thinking Skills.**

These are explained on the next few pages.

Scientific Methods vs The Scientific Method

(See page 37 for the characteristics of each of these.)

The term, scientific methods, had real meaning in prior centuries when scientists were our principal problem solvers. Today, it would be more precise to use a collective term such as "problem solving methods" for the creative, non-logical, logical and technical methods used in science and general problem solving under the stages of the scientific method. In science literature, the most common alternate word for "scientific methods" is "techniques."

Proceeding Scientifically

This is explained in *Introduction to Logic* (1982) by Irving M. Copi (1917 -)—philosopher, educator, author of books on logic:

> *"As the term "scientific" is generally used today, it refers to any reasoning which attempts to proceed from observable facts of experience to reasonable (that is, relevant and testable) explanations for those facts. The scientific method is not confined to professional scientists; anyone can be said to be proceeding scientifically who follows the general pattern of reasoning from evidence to conclusions that can be tested by experience. The skilled detective is a scientist in this sense, as are most of us — in our more rational moments, at least."*

"Serendipity, the accidental discovery of something valuable is vital to scientific progress. Invention favors the prepared mind."

(Ingredient #12) Creative, Non-logical, Logical and Technical Methods

NOTE. By including these supporting ingredients, the SM-14 formula now (revised 1997), reflects the whole system of science and the system of the complete method of creative problem solving and decision making.

For teaching students and for general understanding of the scientific method we need to properly identify the *working, action, effective, and applied methods* that *produce actual results*. These are used under the first eleven stages of SM-14. "Methods" as used here include such elements and auxiliary actions as:

Processes	Tactics	Approaches	Operations	Programs
Procedures	Techniques	Systems	Strategies	Criteria

There is no exact line dividing types of methods, as one type often blends into another.

Creative Methods

Creativity often involves change, inspiration, or a combination of old ideas to produce a new idea or solution. A body of methods has developed for improving creativity.Four important creative methods are reflective thinking, rest illumination, triggers, and brainstorming.

Non-logical Methods

While it may not be "scientific" to use non-logical methods, nevertheless, in actual practice, scientists and all problem solvers are always using them. Time is often the main reason these are used. Some non-logical methods used result from habits, emotions, trial and error, arbitrariness, haste, frustration, closed mindedness, experimenting, unreasoned opinions, risk taking, intuitive pure guess, etc. Be alert to whether they affect your results favorably or unfavorably. Chance, accidental discovery, fortunate occurrences, unanticipated novelty, effective surprise, and serendipity probably are non-logical methods or ways.

Logical Methods (in the broadest sense)

Any method based on sound reasoning is classified here as logical. Some researchers may apply logical methods based on accepted rules of reasoning standardized by logicians. Usually, though, people use "semi-intuitive" logic resulting from their base of experiences, thinking skills, and knowledge. Examples of well-known logical methods based on reasoning and experience are methods of:

controlled variations	pattern identification	trial and error	falsification
reviewing the literature	artificial intelligence	classification	surveying

Technical Methods

No standard exists to determine what methods to term "technical." A method involving measuring, mathematics, use of tools, instruments, and apparatus can be termed "technical." Since most others are general methods used in all fields and for all types of problems, some authors point out that these technical methods are really the only ones that can accurately be called the methods of science or scientific methods.

(Ingredient #13) Procedural Principles and Theories

Since Galileo's time, basic principles, guides, objectives, and thoughts about "the scientific method" and its use have been discussed and debated. There are no established standards concerning these procedural principles and theories. Controversy exists about some, if not all, of them. Because these do not always apply to every circumstance, they must be considered and applied with an open mind as you pursue problem solving.

The Organized Sciences

The organized sciences have their peer review systems, professional organizations, customs, consensuses of opinion, ethical standards (I recommend NAS's *Responsible Science: Ensuring the Integrity of the Research Process*, Vol. I & II, 1993), and constant debates about theories, methods, what is the structure of science, and what is our "organized body of knowledge." Look to them for leadership in procedural principles and theories, as they have been responsible for these. A few major ones are listed below.

The Objective of The Scientific Method

The basic purpose is to obtain, refine, extend, and apply knowledge, and to seek the "truth," although the "truth" can probably never be determined. Results must always be held open to extension, modification, and even possible replacement.

- **Experimentation** — Testing and experimentation, whether on a blackboard or computer, or in the lab, are usually essential activities in the use of the scientific method. Government standards must be observed in experiments involving people, animals, and the environment.
- **Replicable** — Results must usually be reproducible.
- **A Skeptical Attitude** — A skeptical attitude toward authoritative statements is required in seeking the truth. Data used in your thinking must be "true" insofar as it is possible to determine "truth." It may be useful to define key terminology.
- **Values and Ethics** — As much as humanly possible, researchers should strive to be free of prejudice and bias that often creep into human judgment and action. They must give due credit to their team or collaborators.
- **Infallibility** — No claims should be made that the scientific method produces infallible solutions. State, rather: "On the evidence available today the balance of probability favors the view . . ."
- **Gather All Evidence** — If bias or inadequate effort causes you to ignore or fail to find available contrary evidence, you will not arrive at the "truth."
- **Mathematics** — Quantitative methods should be used whenever possible.
- **Society** — There is a growing interest in the concept that science is a social activity.
- **All Stages of The Scientific Method** — Have various procedural principles and theories peculiar to them. See the Stages 1 to 11.

The Value of the Scientific Endeavor — Procedural Principles and Theories

Dr. Vannevar Bush stated:

Advances in science when put to practical use mean:

- more jobs
- higher wages
- shorter hours
- more abundant crops
- more leisure for recreation, for study and for learning how to live without the deadening drudgery which has been the burden of the common man for ages past

Advances in science will also:

- bring higher standards of living
- lead to the prevention or cure of diseases
- promote conservation of our limited national resources
- assure means of defense against aggression

The flow of new scientific knowledge must be both continuous and substantial

But to achieve these objectives — to secure a high level of employment, to maintain a position of world leadership — the flow of new scientific knowledge must be both continuous and substantial.

Science Has Done Wonders for All of Us Through Its Method

Dr. Vannevar Bush, one of our foremost scientists and who aided the WWII effort and the establishment of the National Science Foundation after the war, aptly described the value of scientific endeavor when he stated in 1945:

> *"Advances in science when put to practical use mean more jobs, higher wages, shorter hours, more abundant crops, more leisure for recreation, for study, for learning how to live without the deadening drudgery which has been the burden of the common man for ages past. Advances in science will also bring higher standards of living, will lead to the prevention or cure of diseases, will promote conservation of our limited national resources, and will assure means of defense against aggression. But to achieve these objectives — to secure a high level of employment, to maintain a position of world leadership — the flow of new scientific knowledge must be both continuous and substantial."*

It is this "flow of new scientific knowledge" from the scientific method that has earned it these well deserved praises:

- "the greatest discovery of science" and
- "the greatest idea of all times."

"Science is an imperfect but phenomenally successful process."

(Ingredient #14) Attributes and Thinking Skills

The quality of human activity applied to the various stages and action methods involved in the scientific method determines the quality of results achieved. The fame of the scientific method results from the high degree of development of personal attributes and thinking skills that scientists have used in the scientific method. There is some overlap between attributes and thinking skills. Scientists are human and therefore not perfect, but their overall accomplishments have achieved phenomenal benefits for society. The use of their method spread to all domains.

Personal Attributes

A definition of personal attributes also includes character traits, aptitudes, skills, values, attitudes, etc. The number of desirable attributes mentioned in the problem-solving literature is great. Those most frequently mentioned include:

Honesty	Flexible	Logical Reasoner	Attitude
Sensitivity	Skeptical	Suspend Judgment	Open Minded
Motivated	Communicator	Team Worker	Curiosity
Organized	Seek Truth	Passion for Subject	Courage
Creative	Emotional Stability	Knowledgeable	Experimenter

There is no standard combination that is "best." Your success in life depends on developing desirable personal attributes and improving your undesirable ones.

Thinking Skills

In this limited space, I can only impress on you the need to develop your ability to learn and use the thinking skills necessary to adjust to the many changes in our fast-developing world. We will consider the two primary thinking skills which are always used in problem origination, solving, and challenge of solution. They are basic ways of thinking and are termed induction and deduction.

Induction

This is another controversial subject. Some philosophers have advanced theories that claim there is no such thing. For you and me, however, the standard textbook definition is understandable. Professor Huxley gave this example many years ago:

Suppose you bit these small, hard, green apples. Each one tasted very sour.

You then make a generalization that all small, hard, green apples are probably sour. This is inductive reasoning (i.e., *from the specific or particular to the general*).

Deduction

Then you picked up this small, hard, green apple:

By deductive reasoning (i.e., *from the general to the specific*), you decide it must be sour, too. Many of the thinking skills you need, are mentioned in this booklet.

Famous Examples of Attributes and Thinking Skills

John Dewey (1859-1952), educator-philosopher, wrote many books. The most famous is *How To Think*. He was a great advocate of reflective thinking. He asserted that "the method of science-problem solving through reflective thinking should be both the method and valued outcome of science instruction in America's schools."

Thomas H. Huxley, a famous 19th-century English philosopher, claimed, "*We are all scientists.*" He reasoned that "the method of scientific investigation is nothing but the necessary mode of working of the human mind." This is what makes SM-14 such a fundamental formula.

Motivation and Self-discovery Hold the Key to Success and Improve the Quality of Human Activity

You can set standards to force people to learn and thus accomplish a little more. But real and continued results depend on proper motivation. With our explosion of knowledge, students and adults must improve their learning to learn skills. One of the basic ways to do this is to use The Scientific Method.

Many studies have shown that students are bored with the usual subject-oriented curricula. They welcome curriculum where inquiry, discovery, methods and self-selection of real life problem solving are included. But it is essential they be taught a formula for the stages of mental activity of the problem solving process.

"Man" is claimed to be a problem solving, skill using, social animal. Allowing self-selection of problems to solve and, a formula to follow such as SM-14, prompt self-discovery of peoples talents, potentials, weaknesses and the motivation of:

Curiosity	Recognition of peers
Thrill of discovery	Mental challenges
Personal well being	Job well done
Social contacts	Desire to know
Competition	Enjoyment of work
Personal values	Love

Finally, no results can be obtained without effort and motivation is the fuel that ignites energy.

"Be endlessly curious — watch for surprises."

Practical Help With Everyday Problems & Decisions

The full SM-14 formula, which you have just read, is usually for complex, ill-structured problems that require research and study. However, problems come in a variety of complexities. Here is a shortened formula:

SM-7 For Intermediate-Type Problems and Decisions

(Can also be used as a preliminary or introduction to teaching the full SM-14 formula)

Stage No.	SM-14 No.	SHORT NAME: SM-7 Short Scientific Method — 7 Stages, Labeled A to G
A	1	***Curious Observation***. Find a problem.
B	2	***Is There A Problem?*** Consider purpose, define problem, and estimate requirements to solve problem, all in relation to the time available.
C	4	***Search - Explore***. Review and reflect mentally for solutions. If important enough and time is available, gather evidence as described on Pages 15. Your intuitive base may supply you with answers.
D	5	***Alternative Solutions***. Be sure to devote enough time to generating logical or creative alternative solutions. See pages 17, 38 and 39.
E	6	***Evaluate***. If it is an important problem or decision, you must evaluate, rate, and challenge all possible solutions. Again, memories of past experiences in your intuitive base may be of help.
F	7	***Guess - Hypothesis***. Time may force you to settle for "good enough."
G	11	***Take Action!***

Instantaneous Decisions and Problem Solutions

In the course of a day you make hundreds of simple decisions and problem solutions, usually based on your intuition. They are called by such names as:

Snap judgment	Quick guess	Habit decision
Intuitive decision	Trial and error solution	Instantaneous decision
Leap of understanding	Good enough	Shoot from the hip
Emotional decision	Off the top of your head	Arbitrary guess
Immediate apprehension	Jumping to a conclusion	Hasty decision

Many of these solutions and decisions are really simple, unimportant, and in the habit-type class. Others are of varied importance that you make instantly because of time frames, a good-enough answer will suffice, or you have self-confidence in your intuition. Since some may be important, too many errors can hurt your success, relationships, or reputation. Therefore, it is important to develop your intuition.

"Man is a problem-solving, skill-using, social animal."

Scientific Methods vs. The Scientific Method

Characteristics	Scientific Methods	The Scientific Method
Name	All problem solving process methods or technical methods	The system of science and the problem solving process in all fields
Purpose	Methods and Techniques for use at the stages of the problem solving process	Guide and system to reliable knowledge in all subject matter areas
Division of Method	Sub-Master, Auxiliary and Action	The Master Method
Stages or Steps	Will vary with specific method	Eleven major stages
Sequential	Yes—some may be rigid	Yes—but highly flexible in use
Repeatable	Yes—but many changing at all times	Yes—Stages unlikely to change
Range	Specific to subject areas	Universal to nature and humans—is subject neutral
Reliability	Depends on method, reliability of some can be expressed as percentage	Best of all knowledge methods or guides
Application & Human Activity	Since specified as "scientific," must be to "standards" of scientific and research communities when applied	Since specified as "scientific," must be to "standards" of scientific and research communities when applied

Scientific Methods

The words "scientific methods," as used today, refer to the creative, non-logical, logical or technical methods or techniques used in the problem solving process such as during the stages of the scientific method. In a strict sense, there are no scientific methods (Popper 1983). In a narrow sense, the only scientific methods are the technical ones that usually involve the use of tools, instruments and apparatus (Wolf 1930). In a wide sense, scientific methods are any type of method used according to the usual high quality of application by scientists. Thus, most problem solving methods used "scientifically" can be called a scientific method (Copi 1982).

The Scientific Method

The term "the scientific method" represents the general pattern of the types of mental activity stages (usually aided by physical activities) that occur in the master method, which we use to obtain, refine, extend and apply knowledge in all fields. Over all, it represents the system of science and the complete problem solving process.

Stage #5 — Supplementary Page

Innovation and Creativity are very important — study the next two pages carefully!

Some Ways to Be Innovative and Creative

The Thinker

Just reflective thinking
8 hours produce 2 good ideas
(1 for each 4 hours)

Group Brainstorming

In a 2-hour session with
4 people, 8 good ideas are produced
(4 for each 4 hours)

SEAGEE

Search
Explore
Alternative Ideas
Gather Evidence
Evaluate
Educated Guess

8 hours produce
16 good ideas
(8 for each 4 hours)

Be More Productive — Trigger Your Mind

- Read, skip and skim publications, search the internet to find existing ideas that can be used "as is" or can be adapted to your needs.
- Find articles, opinions, news and advertisements that stimulate or trigger reflective thinking, imagination, illumination, gradual insight or long-term memory as well as working memory. This produces new ideas, concepts, leads or clues.
- Use library, subject files, telephone, fax machine, computer and discussions with others. Have a continuous learning program.

"You learn to solve problems by solving a large number of problems."

Stage #5 — Supplementary Page

Norm Edmund's Advice on How to
Be More Innovative and Creative

1 **Be a perpetual innovator** — someone who seeks out, adapts and implements ideas — new or old. Actively look for ideas by reading, skipping, skimming through many periodicals, books, reports, catalogs, the internet, etc. Also:

Experiment	Brainstorm	Attend conferences and exhibits
Search files	Have discussions	Use computer idea programs
Travel	Sense felt needs	Browse through stores, etc.

2 **Change your behavior and self-image.** Be progressive, develop necessary attributes and motivation. Develop a love for new ideas, new things, new ways, new technologies, new systems. Put your ideas in writing.

3 **Take action!** Have the courage and self-confidence to be an innovator. Dare to be different! Failure will occur — but we learn from our mistakes. Emotions can aid creativity — control stress. Be persistent.

4 **Welcome change and challenge of problems** — be open-minded, flexible.

5 **Apply ideas** to every facet of your life — in your personal affairs, career, school, business — everywhere. Always ask: In what alternative and better ways can it be done? Generate innovative and creative solutions, ideas, concepts, and theories. Develop a sense of humor. Be sensitive to opportunities. Use checklists.

6 **Study innovation, change and creativity** as well as how to win idea acceptance. Educate yourself. Take any courses available. Develop a passion for your problem. Learn to be a good team member, leader, and perpetual innovator.

7 **Be curious and observant.** Develop a spirit of inquiry. This is the way to originate problems. Practice using the complete method of creative problem solving. Avoid constraints on your thinking. Spot key factors.

8 **Ask What? Why? Which? Where? When? Who? How? If?** Constantly reflect on all aspects of your problems. Don't pre-judge ideas too soon. Don't let your ego stop you from saying, "I goofed!"

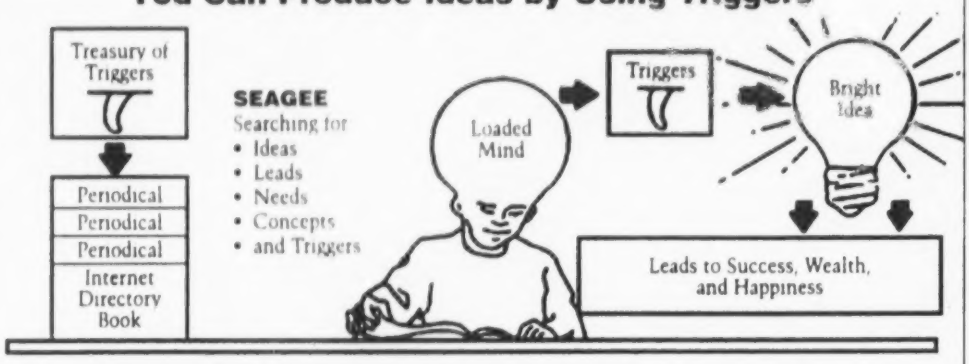
9 **Develop your reflective thinking ability and thinking skills.** Daydream about your problem. Jump back and forth among logical, critical, judicial, imaginative, and wild thinking. Improve through study and practice.

10 **Build your knowledge and intuition base** through reading and other activities. Keep neat files. Learn how to research, to visualize.

11 **With a loaded mind, use triggers** to stimulate ideas, insight, and illumination. Utilize activities listed in #1 above to trigger your storehouse of memories and connect with what you read, hear, see, or think, thereby producing ideas by gradual insight or illumination. Be sensitive to opportunities.

12 **Load your mind** with data, basic principles, theories, and concepts about your problem — REST — then be sure to start thinking of your problem again. Gradual insight or a leap of the imagination may occur.

You Can Produce Ideas by Using Triggers



(A) Watch for ideas which you can use "as is," or adapt to suit your own needs.

(B) Load your mind with data, principles and concepts related to your problem. Then watch for articles and advertisements containing triggers to set off:
1. Flash of illumination (leap of imagination).
2. Reflective thinking leading to gradual insight.

(C) Record idea immediately.

(D) Triggers bring out of long-term memory things not always in working memory.

Try It . . . It Works!

You Can Produce Ideas and Solutions with Rest-Illumination or Rest-Reflective Gradual Insight

First — Load your mind with (in relation to your problem:
- Information
- Theories
- Data
- Concepts
- Basic Principles

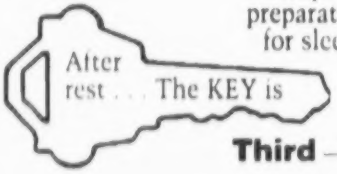
Second — Rest your mind by:

Sleep or preparation for sleep

Vacation Travel Hobby

Exercise Shower Grooming

Work on a different project



Third — Don't just wait. You ***must start*** to think reflectively about your problem again.

EUREKA! A Flash of Illumination . . .
Or, more often, a gradual insight to an . . .
Idea • Solution • Decision • Lead • Clue • Theory • Concept

Write it down immediately!

Decision Making Is Problem Solving

The stages of decision making and problem solving are the same.

- A decision is basically a problem, so, the stages of decision making are the same as those for problem solving.
- In all stages of problem solving there are constant decisions to be made. Some are so important they become a sub-problem of the main problem.
- Today, the trend in business and industry is to push decision making further down in the organizational chart.
- A leaders job is not only making decisions and solving problems but also seeing that subordinates make correct decisions and solve problems.

Here is a rating scale for problem solvers, decision makers and others. You can make as many copies as you want. Larger size one is available from us.

THE EDMUND RELIABILITY SCALE

Our society is becoming increasingly more complex, team-oriented and adversarial each day. A rating scale such as the one shown below may be of some use. Here is my version of a scale that can be used by a person evaluating his own opinion or conclusion. The scale could also be used by a team leader, scientist, businessman, attorney, judge, juror, etc. to evaluate someone's opinion, testimony, or conclusion hopefully reached by following the stages of the scientific method. By multiplying the raters' own degree of experience in a given subject with the score he/she assesses to an individual's opinion, testimony, conclusion, etc., we can arrive at a total score helpful in determining reliability. You can develop variations of the suggested way to use this scale (shown in reduced size here) or a similar one. **Example:** The numerical units could be interpreted to represent money, time, sales, profit or plans and more. The objective of the scale is to bring method and criteria, hence obtaining reliable ratings.

Rating Scale for:			
Knowledge reliability	**Decisions**	**Theories**	**Plans**
Problem solutions	**Testimonies**	**Criteria**	**Ideas, etc.**
Rater's name and title		Rater's level of experience (CIRCLE) LOW 0 1 2 3 4 5 HIGH	
WORST FOR RATING SUBJECT: Circle number you believe applicable BEST -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5 +6 +7 +8 +9 +10 If you rated a 0 please check reason: ❒ Not Sure ❒ Don't Know ❒ Neutral ❒ No Effect			
Subject	Date	Score _____ x _____ = _____ Rater's level of experience x subject's rating = overall score	

Establish your own criteria to Overall Score—for example:

Plus Scores: 1 to 16 = C (Average) 17 to 32 = B (Above Average) 33 to 50 = A (Excellent)
0 Scores: Not Sure, Don't Know, Neutral, No Effect
Minus Scores: Indicate degree of failure, unreliability, inaccuracy, disaster, etc.

SM-14 Is Also The Method of Invention and Creativity

While researching, I found only one large survey pertaining to the method of inquiry, discovery, invention, and creativity—which was in Joseph Rossman's excellent book, *Industrial Creativity* (1930). While the survey is an old one, the basics have remained the same. This survey questioned 710 inventors (inventing is, after all, one of the many forms of use of SM-14), asking them to state what methods they followed while inventing. Rossman's careful analysis reduced their inventing procedures to the list in the left-hand column below. The right-hand column contains the SM-14 stages and ingredients. Note the similarities!

Rossman's Survey—Method of Invention (1930)	**Compare to the SM-14 Formula**
1. Observation of need or difficulty	1. Curious Observation
2. Analysis of the need	2. The Problem 3. Goals, Planning
3. Survey of all available information	4. Search—Explore
4. Formulation of all objective solutions	5. Alternate Solutions
5. Critical analysis of these solutions for their advantages and disadvantages	6. Evaluate Evidence
6. Birth of the new idea-the invention	7. Guess—Hypothesis
7. Experimentation to test the most promising solution; the selection and perfection of the final embodiment by some or all of the previous steps	8. Challenge Hypothesis 9. Reach Conclusion 10. Suspend Judgment
Inventors left "Take Action" as understood.	11. Take Action
SM-14 includes these as important supporting ingredients, especially valuable for teaching →	12. Methods 13. Procedural Principles 14. Attributes—Thinking

Current Osborn-Parnes Process
Objective Finding
Fact Finding
Problem Finding
Idea Finding
Solution Finding
Acceptance Finding

Creative Problem-Solving Process Sponsored by Creative Education Foundation

The formula to the left evolved from the one that Osborn originated and included in the first edition of *Applied Imagination* in 1953. A revised edition of this excellent book is still in print (available from CEF). All problem-solving methods are just variations of the centuries old scientific method. This variation is better than most, as it stresses both finding problems and creative idea finding. As a result of the Creative Education Foundation's efforts, it has been used in thousands of seminars and classes and has been included in hundreds of books. If you will compare this formula to SM-14 (above right column), you will note that SM-14 is more complete and the terminology is more explanatory. As part of standardization, I recommend that everyone interested in creative problem solving use the SM-14 terminology.

Scientific Management

There has been a great deal of misunderstanding about what scientific management and the management sciences really are. These two concepts depend upon the proper use of the scientific method (SM-14), which is basically a complete method of creative problem solving and decision making.

Taylorism is not scientific management!

Frederick W. Taylor pioneered and introduced many management concepts. He is credited with being "The Father of Scientific Management" for his work started in the late 1800's. Many believe that Scientific Management consists of the concepts about time and motion study, he introduced. Study has proven, though, that he merely applied his version of the scientific method for originating problems and for solutions, thus arriving at his conclusions or hypotheses. Scientific Management should not be restricted to any one person's concept or approach to it, or to any one phase of management. It depends on the proper use of the scientific method.

Imperfect, But Still A "Phenomenally Successful Process"

Applying the scientific method (SM-14) to management is imperfect because the human element is always present and because things in the social sciences are less exact than in the natural sciences but is far superior to such ways and processes as:

Hunch or gut instinct	Seat of pants	Doing your "thing"
Haphazard guess	Uneducated guess	Applying existing knowledge
Common sense	Rule of thumb	Outdated intuition
Superficial analysis	Trial and error	Pig in the poke
Management by exception	Chaos	"We always do it that way"
Walk-around management	Fad of the day	Quick fix

While the application of SM-14 is far superior to the above, there are times when some of these serve a useful purpose (trial and error is always a basic way to progress). Proper use of SM-14, however, should prevent many failures due to poor hunches and guesses, quick fixes, and applying the fad of the day.

Management Science

To have a "science," you must basically have a domain or sub-domain with a group of practitioners applying the scientific method to their research to obtain, refine, extend and apply knowledge. The conclusions reached must be communicated, published in professional journals thus being subjected to peer review with the aim of providing a systematic organized reliable body of knowledge.

Summary

Thus, the basic principle is that to manage scientifically, you must:

- be familiar with the management sciences,
- apply these to your work, and
- to follow the stages of the scientific method and its supporting ingredients on complex problems and decisions.

Your Guide and Worksheet for Applying The Complete Method of Creative Problem Solving and Decision Making (SM-14)

Stages or Ingredients of SM-14*	Space for Comments and Notes Provided Below Method or guide keeps our thoughts en route to new reliable knowledge
1. Curious Observation 	Be alert — What is needed? Be skeptical — Prevent trouble. Discover problems. Ask why?
2. Is There a Problem? Present in form of question	Analyze problem carefully, as Einstein stated: "A problem properly defined is often half-solved."
3. Goals and Planning 	Break problem down into sub-problems. Consider any solutions as tentative till complete Stage 6.
4. Search, Explore, and Gather the Evidence 	Search Internet, books, and other sources. Follow leads. Explore all angles. Build files.
5. Generate Creative and Logical Alternative Solutions 	Search for ideas, read publications to trigger your imagination. Think reflectively.
6. Evaluate the Evidence 	If possible, chart evaluations of your tentative solutions or theories. Compare and test.

*Use shaded stages for less complex and less important problems and decisions. (Continue

7. Make the Educated Guess (Hypothesis)	State your working hypothesis explicitly. Make predictions for testing.
8. Challenge the Hypothesis	Test. Experiment. Control variables. Attempt to falsify.
9. Reach a Conclusion	Can others test and confirm your conclusions?
10. Suspend Judgment	Keep an open mind and be ready to accept new evidence. Knowledge is forever changing.
11. Take Action	Submit your theory to peer review or take other appropriate action.

Below are the Supporting Ingredients used at all the preceeding stages of SM-14

12. Creative, Non-Logical, Logical, and Technical Methods	Use all types of action methods at all stages to actually accomplish results.
13. Procedural Principles and Theories	Follow those used by researchers everywhere, but "anything goes" (if ethical).
14. Attributes and Thinking Skills	Be honest, team worker, communicator, etc. Use creativity — reason logically.

*Use shaded stages for less complex and less important problems and decisions.

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About the Author

Edmund has not made an original discovery but only has re-discovered an old tried and workable one. He has been able to do what no one else has done—make a better evaluation and condensation of what the scientific method really is and then present it in a more comprehensive form that's easier to learn and teach.

Professor Ritchie Calder in *Science in our Lives* (1962) states: "A great discovery depends on three things—The Method—The Man—The Moment."

The Moment

Today we are in the "Age of Knowledge." Now is the moment to bring rationality to our understanding of the method of knowledge—The Scientific Method.

The Man

Norman Wilson Edmund was born in Boston, Massachusetts in 1916 and moved to Camden, NJ, in 1920 As a boy Edmund was an avid reader, newspaper boy, and Boy Scout. He studied self-improvement and was voted "most studious" in junior and high school. Upon graduation from high school in 1935, during the depression, he enrolled in evening course at the Wharton School at the University of Pennsylvania. Graduating in 1939, he won the same award he had received at high school graduation—"Most Outstanding for the Combination of Scholarship and Extra-curricular Activities."

Immediately after graduation, a serious illness forced him to spend two years in the hospital. Back to health at the age of 25, he was again living with his parents when his creativity and entrepreneurial spirit surfaced. In March of 1942, he started a mail order business selling kits of lenses. His office was a card table in his bedroom. He added prisms, war surplus optical items, telescopes and scientific items. Soon, thousands of experimentally inclined individuals and all the major research labs and universities were buying his products. Each month, he read 200 periodicals looking for ideas.

Upon retirement in 1975, his bedroom office was now a 68,000 square-foot plant.

Years followed with leisurely life in Florida, where he spent his days yachting and fishing. Then in 1989 he gave it all up to research The Scientific Method.

The Method

In researching the nature of The Scientific Method, Edmund's high degree of creativity was now self serving. He used the scientific method process to explore what the method was—i.e. the science of science, sometimes called methodology, philosophy of science or epistemology. The thinking skills he had acquired from being an avid reader, perpetual student, and the experience from his 35-year career of being the top problem-solver at Edmund Scientific, had prepared him for this quest.

Therefore, without any hesitation, I highly recommend that you seize this unique opportunity to acquaint yourself with The Scientific Method (SM-14) formula as expounded in this booklet.

J. Raymond Parent, *past vice-president,*
André-Laurendeau College, Lasalle. Québec, Canada

Praise of SM-14 Formula . . .

"Your proposal to teach SM-14 not only to young scientists but also as part of general education is excellent, and I wish you success."

— Dr. W.I.B. Beveridge, author of the famous and often cited books, *The Art of Scientific Investigation* (1957) and *Seeds of Discovery* (1980)

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"It has often been said that the greatest discovery in science was the discovery of the scientific method of discovery." — Dr. James K. Feibleman, author of *Scientific Method* (1972)

"The greatest invention of the nineteenth century was the invention of the method of invention."

— A.N. Whitehead, (1926)

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